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(54) METHOD OF CONTROLLING A BI-FUEL GENERATOR SET

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(58) **Field of Search** .... 123/563, 3, 27 GE, 123/41.29, 41.33, 198 D, 198 DB, 435, 526, 540, 541, 575; 60/599

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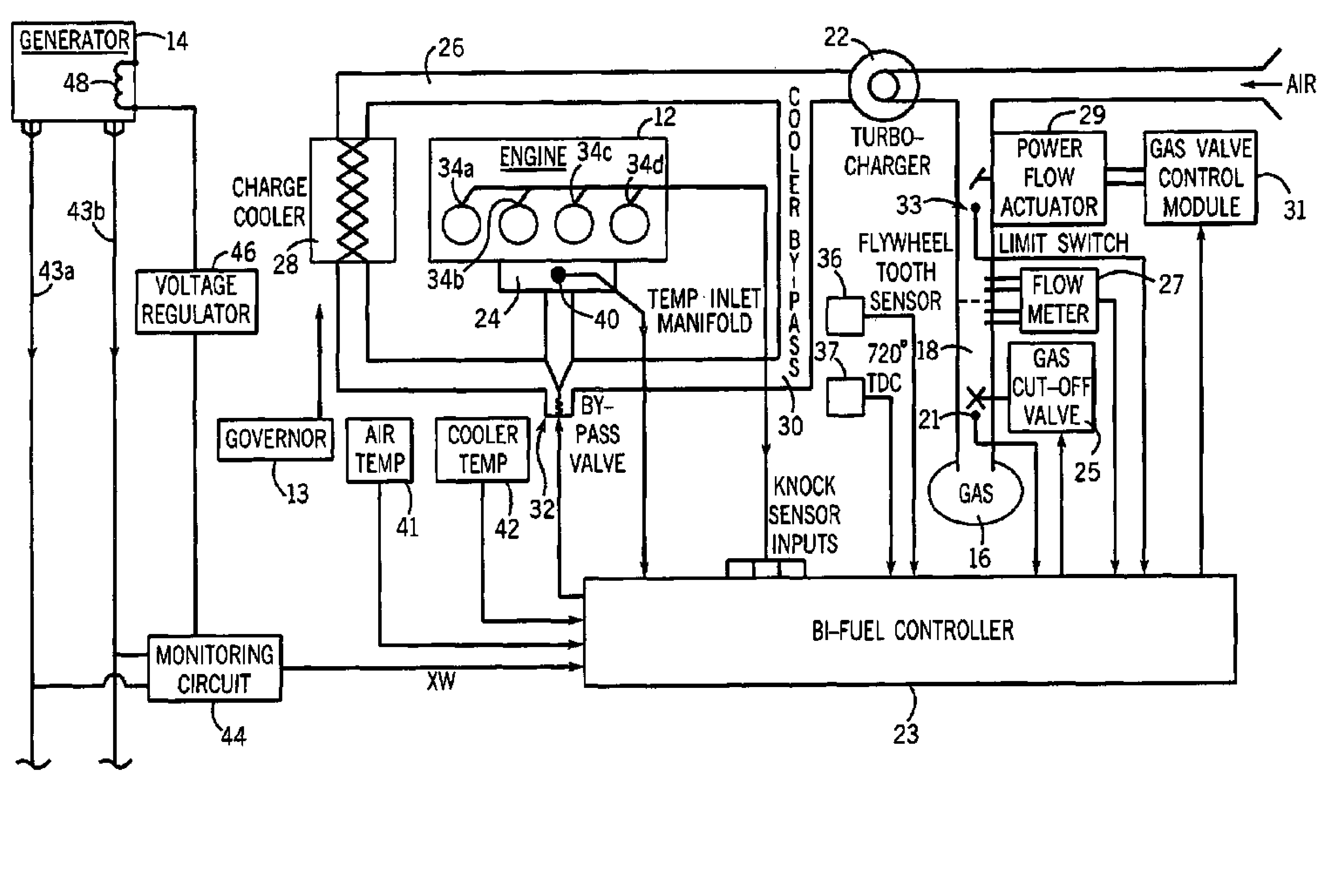
(57) ABSTRACT

A method is provided for controlling a bi-fuel generator set. The generator set includes a controller, a generator for generating electrical power, and an engine for driving the generator. A flow of gaseous fuel is provided, and operation of the engine and the generator is monitored. The flow of gaseous fuel is adjusted in response to various predetermined operating conditions on the engine. In addition, the flow of gaseous fuel may be selectively passed through a charge cooler remote from a radiator for the engine. The flow of gaseous fuel may be cooled by the charge cooler in response to certain operating conditions on the engine.

30 Claims, 4 Drawing Sheets



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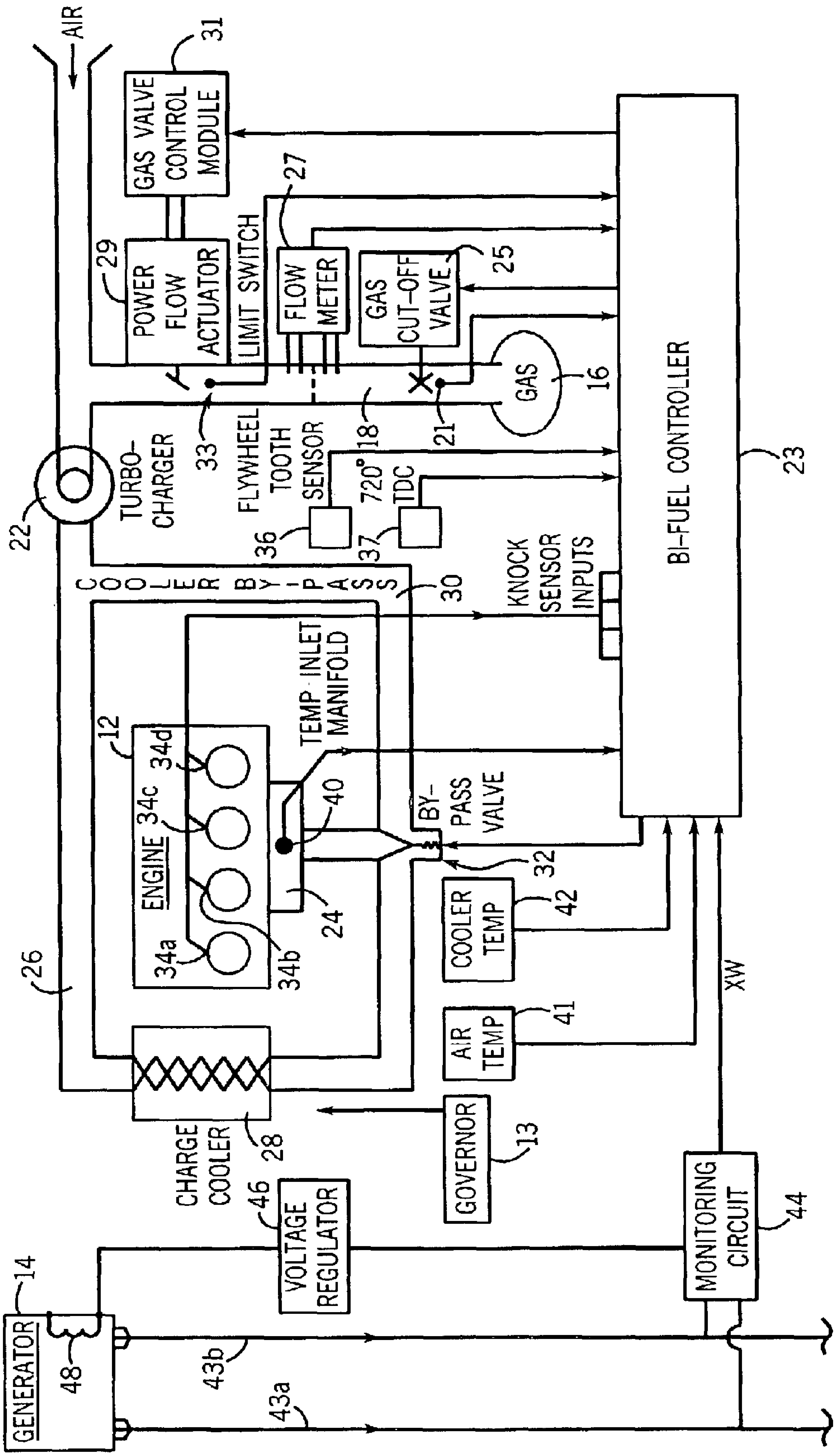
AIR
GAS VALVE CONTROL MODULE
31
POWER FLOW ACTUATOR
29
LIMIT SWITCH
FLOW METER
27
GAS CUT-OFF VALVE
25
GAS
16
21
18
33
TURBO-CHARGER
22
FLYWHEEL TOOTH SENSOR
36
720° TDC
37
BI-FUEL CONTROLLER
23
COOLER BY-PASS
30
KNOCK SENSOR INPUTS
ENGINE
12
34a
34b
34c
34d
TEMP INLET MANIFOLD
40
24
BY-PASS VALVE
32
COOLER TEMP
42
AIR TEMP
41
XW
26
CHARGE COOLER
28
GOVERNOR
13
VOLTAGE REGULATOR
46
MONITORING CIRCUIT
44
GENERATOR
14
48
43b
43a

FIG. 1

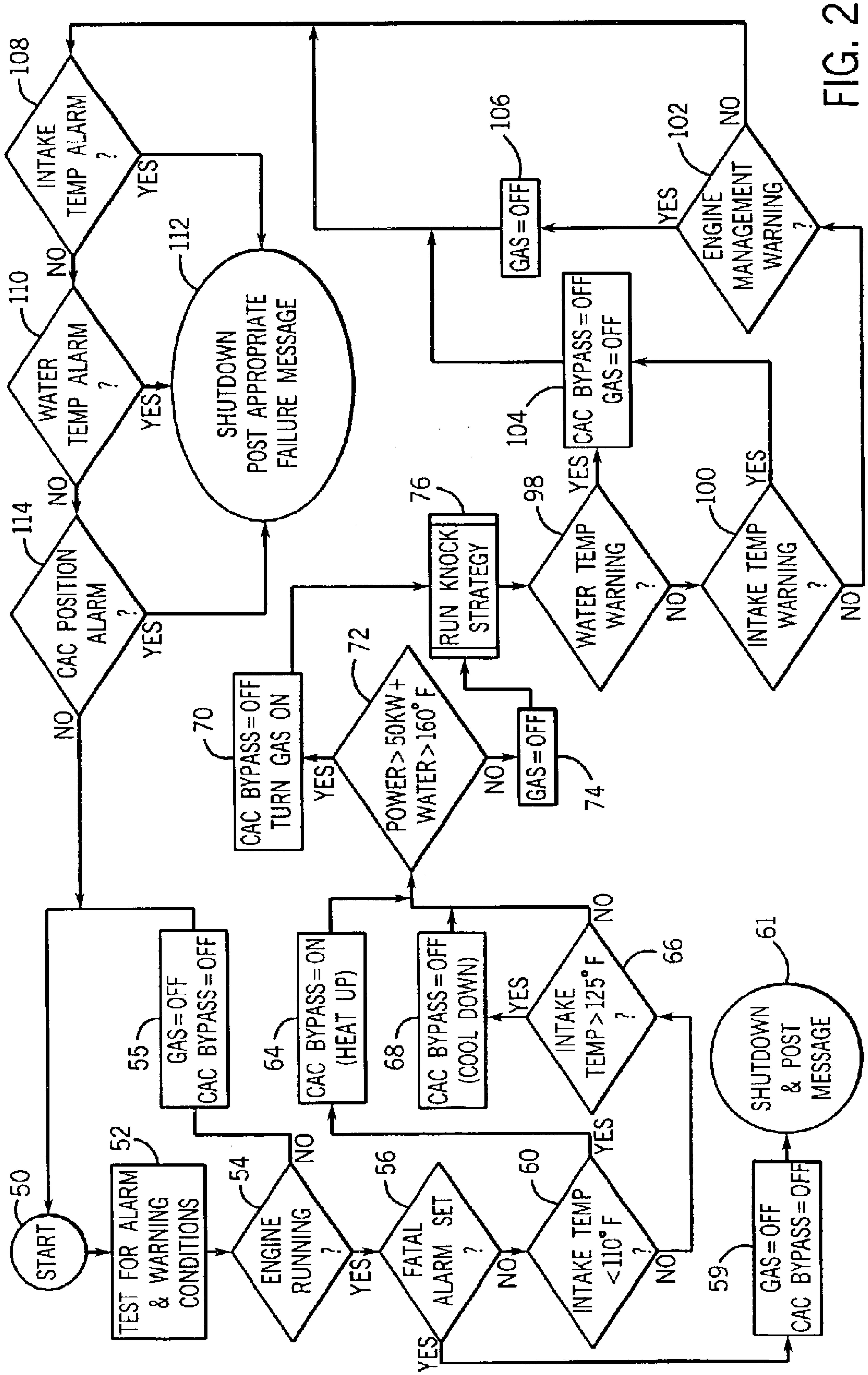
50
START
52
TEST FOR ALARM & WARNING CONDITIONS
54
ENGINE RUNNING ?
YES
NO
55
GAS=OFF CAC BYPASS=OFF
56
FATAL ALARM SET ?
YES
NO
59
GAS=OFF CAC BYPASS=OFF
61
SHUTDOWN & POST MESSAGE
60
INTAKE TEMP <110° F ?
YES
NO
64
CAC BYPASS=ON (HEAT UP)
66
INTAKE TEMP>125° F ?
YES
NO
68
CAC BYPASS=OFF (COOL DOWN)
72
POWER>50KW + WATER>160° F
YES
NO
70
CAC BYPASS=OFF TURN GAS ON
74
GAS=OFF
76
RUN KNOCK STRATEGY
98
WATER TEMP WARNING ?
YES
NO
104
CAC BYPASS=OFF GAS=OFF
100
INTAKE TEMP WARNING ?
YES
NO
102
ENGINE MANAGEMENT WARNING ?
YES
NO
106
GAS=OFF
108
INTAKE TEMP ALARM ?
YES
NO
110
WATER TEMP ALARM ?
YES
NO
114
CAC POSITION ALARM ?
YES
NO
112
SHUTDOWN POST APPROPRIATE FAILURE MESSAGE

FIG. 2

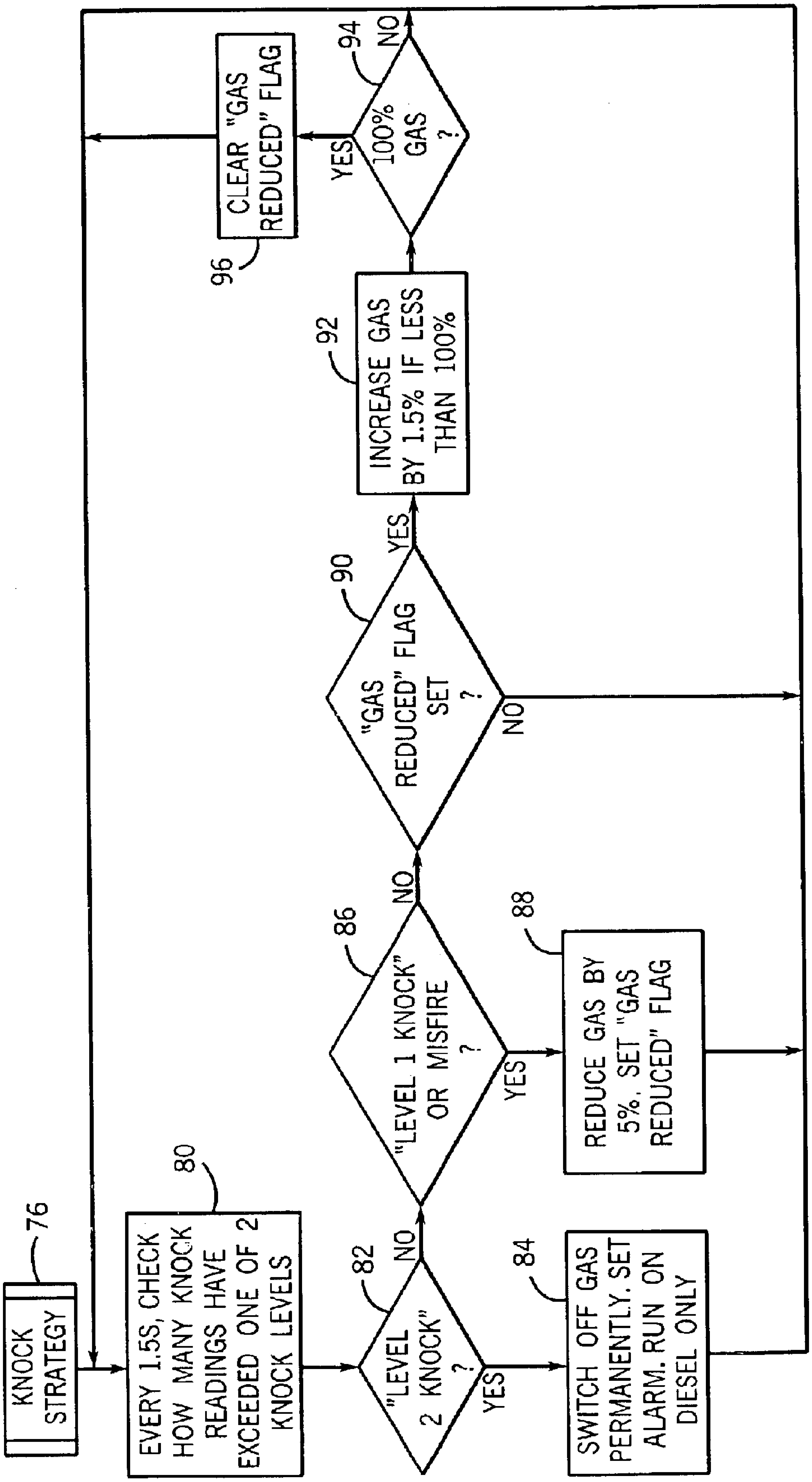
76
KNOCK STRATEGY
80
EVERY 1.5S, CHECK HOW MANY KNOCK READINGS HAVE EXCEEDED ONE OF 2 KNOCK LEVELS
82
"LEVEL 2 KNOCK" ?
YES
NO
84
SWITCH OFF GAS PERMANENTLY. SET ALARM. RUN ON DIESEL ONLY
86
"LEVEL 1 KNOCK" OR MISFIRE ?
YES
NO
88
REDUCE GAS BY 5%. SET "GAS REDUCED" FLAG
90
"GAS REDUCED" FLAG SET ?
YES
NO
92
INCREASE GAS BY 1.5% IF LESS THAN 100%
94
100% GAS ?
YES
NO
96
CLEAR "GAS REDUCED" FLAG

FIG. 3

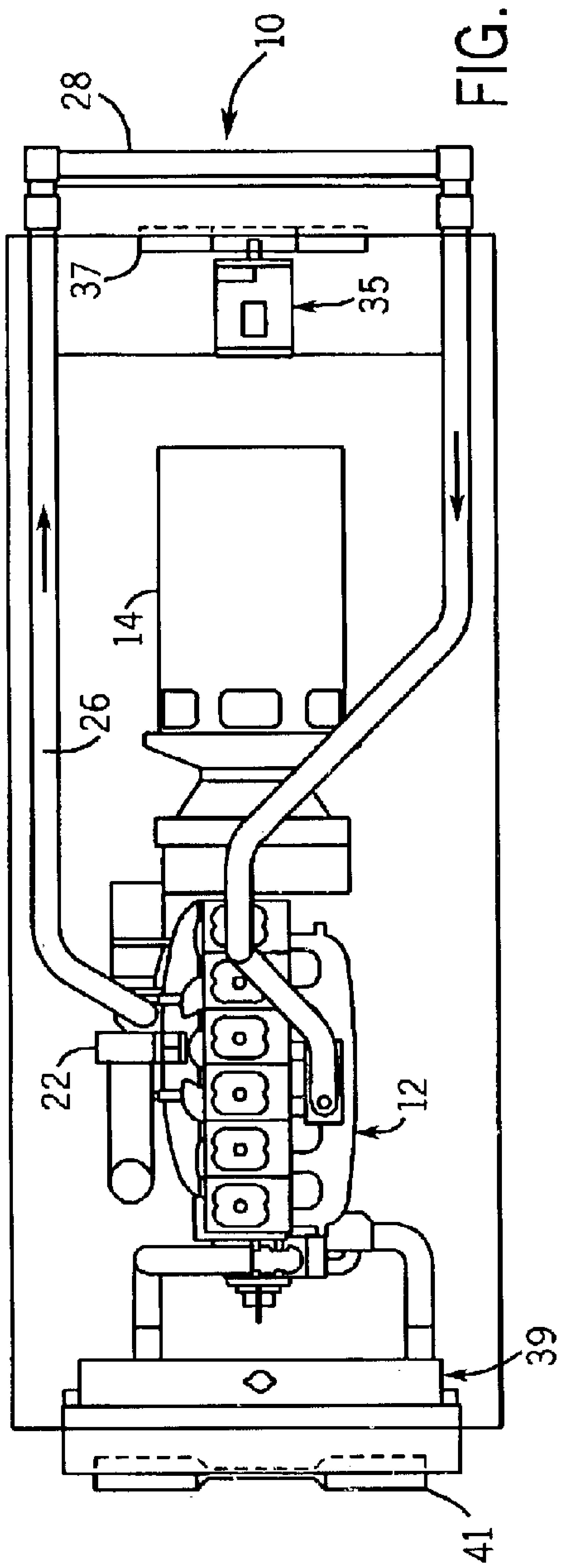

FIG. 4

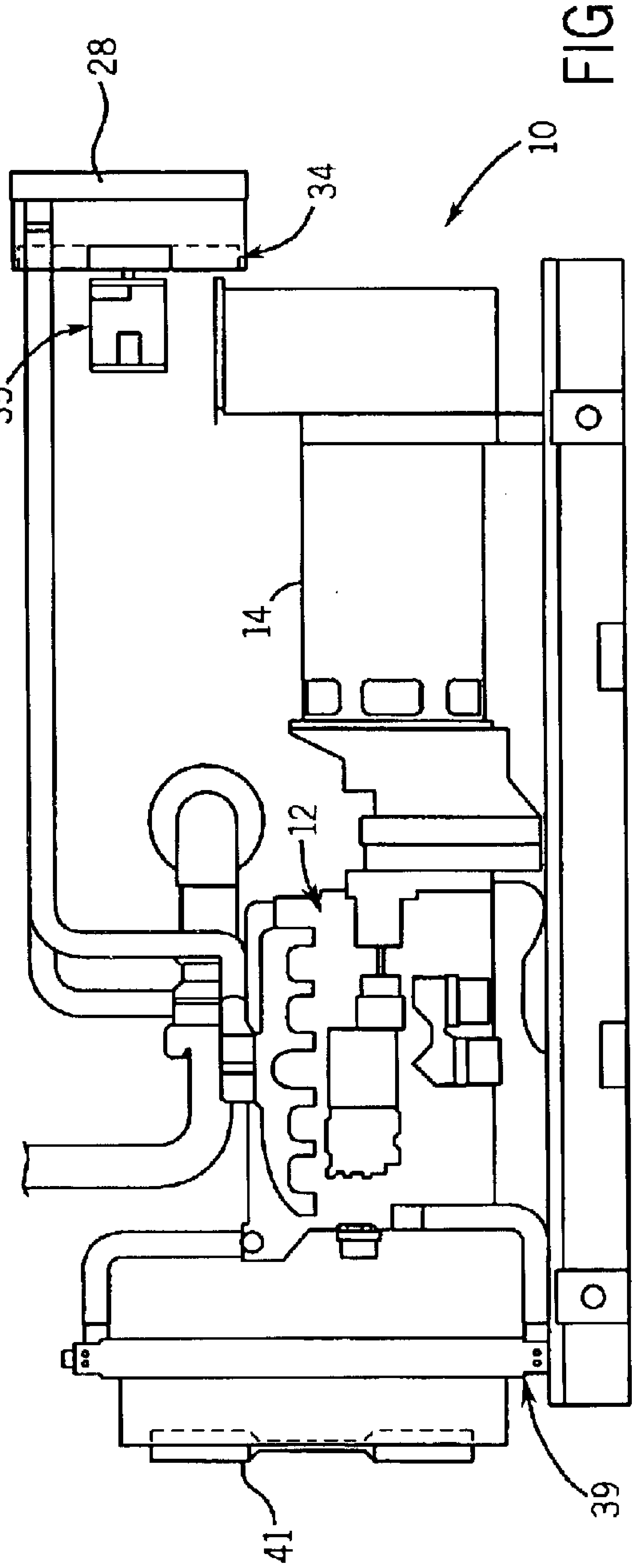

FIG. 5

METHOD OF CONTROLLING A BI-FUEL GENERATOR SET

FIELD OF THE INVENTION

This invention relates generally to engine driven electrical generator sets, and in particular, to a method of controlling and regulating operation of a bi-fuel, engine-driven electrical generator set.

BACKGROUND AND SUMMARY OF THE INVENTION

Engine-driven, electrical generators are used in a wide variety of applications. Typically, an electrical generator utilizes a single driving engine directly coupled to a generator or alternator through a common shaft. The engine is also directly connected to a pressurized fuel source, such as diesel and/or natural gas, in order that the generator may be automatically activated in the event of a power outage. Upon activation of the generator, a fuel and air mixture is provided to the combustion chambers of corresponding cylinders of the engine. The fuel mixture in each combustion chamber is ignited causing an explosion within the cylinders. The explosive forces within the combustion chambers in the cylinders cause linear motion of the pistons within their corresponding cylinders. The linear motion of the pistons is converted into rotational motion by a crankshaft that, in turn, drives the alternator. As is conventional, the driven alternator generates electrical power.

In order to increase the operating efficiency of the generator, it is contemplated to utilize a diesel engine to drive the alternator. As is known, diesel engines may be operated utilizing both diesel fuel and natural gas as the fuel sources. These "bi-fuel" engines operate on diesel fuel for a first predetermined portion of the operating range of the engine and on a mixture of diesel and gaseous fuels for the remaining portion of the operating range. In order to insure proper operation of the engine, it is necessary to continually monitor the volume of gaseous fuel supplied to the engine. If too much gaseous fuel is provided, the engine may lose power or be damaged. On the other hand, if too little gaseous fuel is provided, the engine will operate at a less than optimum efficiency or emissions performance.

In order to regulate the flow of fuels to the engine, control systems of different types have been developed. By way of example, Rieck, U.S. Pat. No. 6,178,927 discloses a gas engine having a control system with a pilot control device for adjusting the operating state of the engine in response to changes in various monitored limiting conditions. A plurality of predetermined limiting conditions are defined such that the control system stops the engine if the operating point of the engine reaches any of the plurality of limiting conditions. In certain applications wherein the load conditions on a generator varies greatly, the operating point of the engine may approach the limiting conditions thereby resulting in the control system stopping the engine. As such, it is highly desirable to provide a more adaptable control system for the generator that adjusts to continually varying load conditions.

Therefore, it is a primary object and feature of the present invention to provide a method of controlling and regulating operation of a bi-fuel, engine-driven electrical generator set that maintains the engine within desired operating conditions.

It is a further object and feature of the present invention to provide a method of controlling and regulating operation of a bi-fuel, engine-driven electrical generator set that minimizes the emissions produced during operation of the engine.

It is a still further object and feature of the present invention to provide a method of controlling and regulating operation of a bi-fuel, engine-driven electrical generator set that is simple and inexpensive to implement.

In accordance with the present invention, a method is provided for controlling a bi-fuel generator set. The bi-fuel generator set includes a controller, a generator for generating logical power, and an engine for driving the generator. The method includes the steps of providing a flow of gaseous fuel to the engine and monitoring vibration of the engine during operation. A vibration signal is provided to the controller in response to vibration of the engine during operation. The vibration signal is compared to the first threshold such that if the vibration signal exceeds the first threshold, the controller reduces the flow of gaseous fuel provided to the engine.

The air temperature at the air intake of the engine is monitored and compared to a threshold. If the air temperature at the air intake of the engine exceeds the threshold, the controller reduces the flow of gaseous fuel provided to the engine. In addition, the electrical power produced by the generator is monitored. If the electrical power exceeds a threshold, the flow of gaseous fuel provided to the engine is cooled.

The method also includes providing coolant for cooling the engine. The temperature of the coolant is monitored such that if the temperature of the coolant exceeds the threshold, the flow of gaseous fuel provided to the engine is cooled. Diesel fuel is also provided to the engine. The volume of the diesel fuel provided to the engine is adjusted in response to the flow of gaseous fuel provided.

It is contemplated to compare the vibration signal to a second threshold such that if the vibration signal exceeds the second threshold, the controller terminates the flow of gaseous fuel to the engine. In addition, it is contemplated to determine maximum flow of gaseous fuel to the engine in response to a load on the engine and the air temperature of the air intake of the engine. The flow of gaseous fuel provided to the engine is then compared with the maximum flow of gaseous fuel. The flow of gaseous fuel provided to the engine is increased if the flow of gaseous fuel provided to the engine is less than the maximum flow of gaseous fuel. Further, if the vibration signal is less than the first threshold, the flow of gaseous fuel to the engine is also increased.

If the temperature of the coolant exceeds a first threshold, the flow of gaseous fuel to the engine is stopped. If the temperature of the coolant exceeds a second threshold, the engine is stopped.

In accordance with a further aspect of the present invention, a method is provided for controlling a bi-fuel generator set having a control, a generator for generating electrical power, and an engine for driving the generator. The method includes the steps of providing a flow of gaseous fuel to the engine and cooling the flow of gaseous fuel. The flow of gaseous fuel provided to the engine may be cooled if the electrical power exceeds a threshold and/or the temperature of the coolant of the engine exceeds a threshold.

The vibration of the engine during operation is monitored and a vibration signal is provided to the controller in response thereto. The vibration signal is compared to a threshold such that if the vibration signal exceeds the threshold, the controller reduces the flow of gaseous fuel provided to the engine. If the vibration signal is less than the threshold, the flow of gaseous fuel provided to the engine is increased. In addition, the vibration signal may be compared to a second threshold such that if the vibration signal exceeds the second threshold, the controller terminates the flow of gaseous fuel to the engine.

The method includes the steps of monitoring the air temperature at the air intake of the engine and adjusting the flow of gaseous fuel provided to the engine in response to the air temperature at the air intake. The temperature of the coolant for the engine is also monitored. If the temperature of the coolant exceeds a first threshold, the flow of gaseous fuel provided to the engine stops. If the temperature of the coolant exceeds a second threshold, the engine is stopped. The speed of the engine may also be monitored such that if oscillations in the speed of the engine are detected, the flow of gas provided to the engine may be reduced.

In accordance with a still further aspect of the present invention, a method of controlling a bi-fuel generator set is provided. The generator set includes a controller, a generator for generating electrical power, and an engine for driving the generator. The method includes the steps of providing diesel fuel to the cylinders of the engine for ignition and providing a flow of gaseous fuel to the engine. The operating conditions of the engine and the generator are monitored and the flow of gaseous fuel to the engine is adjusted in response to predetermined operating conditions on the engine.

It is contemplated to cool the flow of gaseous fuel provided to the engine under certain conditions. For example, the gaseous fuel provided to the engine may be cooled if the temperature of the coolant of the engine exceeds a threshold. Alternatively, the gaseous fuel provided to the engine may be cooled if the electrical power generated by the generator exceeds a threshold.

The step of monitoring the operating conditions of the engine may include the step of monitoring vibration of the engine during operation. Thereafter, a vibration signal may be provided to the controller in response to vibrations. The vibration signal is compared to a first threshold such that if the vibration signal exceeds the first threshold, the flow of gaseous fuel provided to the engine is reduced. If the vibration signal is less than the first threshold, the flow of gaseous fuel to the engine is increased. If the vibration signal is greater than a second threshold, the flow of gaseous fuel provided to the engine is terminated.

The air temperature at the air intake of the engine, the temperature of the coolant for the engine, and the speed of the engine may also be monitored. If the temperature of the coolant exceeds a first threshold, the flow of gaseous fuel to the engine is stopped. If the temperature of the coolant exceeds a second threshold, the engine is stopped. If oscillations are detected in the speed of the engine, the flow of gaseous fuel provided to the engine is reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings furnished herewith illustrate a preferred construction of the present invention in which the above advantages and features are clearly disclosed as well as others which will be readily understood from the following description of the illustrated embodiment.

In the drawings:

FIG. **1** is a schematic view of an engine driven electrical generator set controlled in accordance with the method of the present invention;

FIG. **2** is a flow chart of a portion of the control methodology of the present invention;

FIG. **3** is a second portion of the control methodology of the present invention;

FIG. **4** is a schematic, top plan view of an engine driven electrical generator set; and

FIG. **5** is a schematic, side elevational view of an engine driven electrical generator set.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to FIGS. **1** and **4–5**, a generator set in accordance with the present invention is generally designated by the reference numeral **10**. Generator set **10** includes an engine **12** operatively connected to generator **14** in a conventional manner. It is contemplated that engine **12** take the form of a conventional engine that is capable of operating in either a full diesel mode wherein diesel fuel only is supplied to engine **12** or a bi-fuel mode wherein a fuel mixture of natural gas and diesel fuel is provided to engine **12**.

As is conventional, engine **12** includes pistons that are slidably received within corresponding cylinders thereof. In full diesel mode, diesel fuel is provided to the cylinders of engine **12** and ignited so as to generate reciprocal movement of the pistons. The flow of diesel fuel to the cylinders of engine **12** is controlled by governor **13**, in a conventional manner. The reciprocal movement of the pistons of engine **12** is translated to rotational movement by a crankshaft that, in turn, drives generator **14**. In order to increase the efficiency of engine **12** and reduce the emissions, it is contemplated to operate engine **12** in the bi-fuel mode wherein a mixture of natural gas and air is forced into the cylinders of engine **12**. As hereinafter described, the natural gas contribution to the fuel mixture will vary between 0 percent and approximately 90 percent of the total fuel provided to engine **12**.

As best seen in FIG. **1**, a supply of natural gas is generally designated by the reference numeral **16**. First flow path **18** has an input communicating with natural gas supply **18** and an output communicating with air flow path **19**. Air flow path **19** has an input communicating with an air source, (such as ambient air) and an output communicating with the input of turbo charger **22**. First flow path **18** includes limit switch **21** operatively connected to bi-fuel controller **23** and gas cut off valve **25**. Gas cut off valve **25** opens and closes the first flow path **18** in response to instructions received from bi-fuel controller **23**. In addition, first flow path **18** includes flow meter **27** for measuring the gas flow therethrough and throttle-body actuator **29** for controlling the volume of natural gas provided to air flow path **19**. Throttle-body actuator **29** is operatively connected to control module **31** that is connected, in turn, to bi-fuel controller **23**. Limit switch **33** is provided in first flow path **18** and provides a signal corresponding to the flow rate of the natural gas to air flow path. **19** to bi-fuel controller **23**, for reasons hereinafter described.

The output of turbo charger **22** is operatively connected to the input of engine manifold **24** through first and second paths **26** and **30**, respectively. In response to instructions from bi-fuel controller **23**, bypass valve **32** controls the path (either first path **26** or second path **30**) of the fuel mixture outputted by turbo charger **22**, for reasons hereinafter described. Bypass valve **32** is movable between a first, non-bypass position wherein the fuel mixture travels along first path **26** to engine manifold **24** and a bypass position wherein the fuel mixture travels along second path **30** to engine manifold **24**. First path **26** includes charge cooler **28** for allowing the fuel mixture to flow therethrough. Upon activation, fan drive motor **35** rotates cooling fan **37** to draw ambient air through charge cooler **28** so as to cool the fuel mixture flowing therethrough. As is known, a cooler fuel mixture is less sensitive to detonation. As such, a higher percentage of the total fuel supplied to engine **14** for a given load may be the fuel mixture, as opposed to the diesel fuel. A higher percentage of the fuel mixture in the total fuel supplied to engine **14** increases the efficiency of engine **14** and reduces the emissions generated by engine **14** during operation. In addition, since gaseous fuel is less expensive than diesel fuel, operating at a higher ratio of the fuel mixture to diesel fuel decreases the overall cost of operating engine **14**.

Referring to FIGS. **4** and **5**, generator set **10** also includes radiator **39** operatively connect to engine **12** to receive coolant therefrom. As is conventional, cooling fan **41** draws ambient air through radiator **39** to effectuate a heat exchange with the coolant received from engine **12**. The coolant exits radiator **39** and returns to engine **12** to cool the same. It is contemplated to position charge cooler **28** at an opposite end of generator set **10** from radiator **39** and engine **12** in order to insure that the ambient air drawn through charge cooler **28** is of a minimum temperature thereby maximizing the cooling effect on the fuel mixture flowing therethrough.

As best seen in FIG. **1**, generator set **10** further includes manifold temperature sensor **40** operatively connected to the engine manifold **24** to monitor and measure the temperature of the fuel mixture supplied to the engine manifold **24** of engine **12** and to provide a manifold temperature signal to bi-fuel controller **23**. In addition, air temperature sensor **41** is provided to measure the temperature of the ambient air adjacent engine **12** and a cooling medium temperature sensor **42** is provided for measuring the temperature of the cooling medium or coolant used to cool engine **12**. Air temperature sensor **41** and cooling medium temperature sensor **42** provide corresponding temperature signals to bi-fuel controller **23**. It is contemplated that readings of air temperature sensor **41** be used by bi-fuel controller **23** to adjust the flow of air/fuel mixture to engine manifold **24** of engine **12** based on the calorific content of the fuel that can change with temperature.

Generator set **10** further includes a plurality of knock sensors **34***a–d* operatively connected to engine **12** and flywheel sensor **36**. Knock sensors **34***a–d* may take the form of accelerometers attached to engine **12** to provide feedback signals to bi-fuel controller **23**. It is intended that knock sensors **34***a–d* detect high frequency oscillations of pressure in the cylinders of engine **12** that can lead to mechanical breakdown of engine **12**. By way of example, knock sensors **34***a–d* are connected to engine **12** adjacent corresponding cylinders. For each cylinder firing, the closest knock sensor **34***a–d* is monitored over a specific time interval during which the output signals of knock sensors **34***a–d* are integrated. Bi-fuel controller **23** samples these integrals and compares the samples to a series of thresholds. Thereafter, bi-fuel controller **23** counts the number of samples above each threshold during a specific time period (hereinafter referred to as "the number of knocks"). As hereinafter described, bi-fuel controller **23** adjusts the flow of gas to turbo charger **22** in response to the number of knocks detected during a specific time period.

Flywheel sensor **36** detects each tooth of the flywheel of engine **12** as the tooth passes a fixed point on the enclosure of the flywheel and provides a signal to bi-fuel controller **23** in response thereto. Sensor **37** is mechanically set to send a signal to bi-fuel controller **23** on the compression stroke of one of the cylinders of engine **12**. From such information, bi-fuel controller **23** calculates the speed of engine **12** and the engine firing sequence. This, in turn, allows bi-fuel controller **23** to detect engine speed oscillations such that if the engine speed begins to oscillate above a predetermined threshold, bi-fuel controller **23** will reduce the flow of gas provided to turbo charger **22**. In addition, this information provides bi-fuel controller **23** with a time frame for monitoring knock sensors **34***a–d* for any unusual combustion noises.

As is conventional, generator **14** generates AC voltage having a magnitude and a frequency and an AC current having a magnitude and a frequency on lines **43***a* and **43***b*. The output of generator **14** is monitored by monitoring structure **44** that, in turn, calculates the AC power generated by generator **14** according to the expression:

$$P=I\times V\times pf \qquad \text{Equation (1)}$$

wherein: P is the AC power, I is root means square of the AC current, V is the root means square of the AC voltage, and pf is the power factor (or the cosine of the angular displacement between the voltage and the current). The output power is calculated by monitoring circuit **44** and provided to bi-fuel controller **23**, for reasons hereinafter described.

As is conventional, generator **14** includes an armature winding or exciter **48** that controls the magnitude of the AC output voltage of generator **14**. Voltage regulator **46** acts to increase or decrease the excitation of exciter **48** of generator **14** to the degree needed to maintain the magnitude of the AC output voltage at a desired value. During operation of generator set **10**, monitoring circuit **44** advises voltage regulator **46** of the desired magnitude of the AC voltage and voltage regulator **46** raises or lowers the magnitude of the AC voltage provided by generator **14**.

Referring to FIG. **2**, in operation, bi-fuel controller **23** is initialized, block **50**, upon activation of generator set **10**. Bi-fuel controller **23** scans the various sensors heretofore described to determine if any alarm or warning conditions are present on engine **12**, block **52**. In addition, bi-fuel controller **23** determines if engine **12** is running, block **54**. If engine **12** is not running, bi-fuel controller **23** confirms that gas cut-off valve **25** is closed and that bypass valve **32** is in the non-bypass position, and initializes the various sensors of generator set **10**, block **55**.

As engine **12** is started, a vacuum is generated in the cylinders of engine **12** causing governor **13** to open the throttle of engine **12** and allow for the flow of diesel fuel to the cylinders of engine **12**. As is conventional, the diesel fuel is ignited so as to cause the reciprocal movement of pistons contained in the cylinders of engine **12**. Thereafter, governor **13** controls the flow of diesel fuel to the cylinders of engine **12** such that engine **12** operates at a desired engine speed. Once it is determined that engine **12** is running, block **56**, bi-fuel controller **23** continually monitors the various sensors for generator set **10**, as heretofore described, block **58**, to determine if a fatal alarm condition is present on engine **12**. By way of example, a fatal alarm condition may include, but is not limited to, extreme engine temperature, a lack of oil pressure or the like. If a fatal alarm condition is detected, gas cut-off valve **25** is closed, block **59**, and operation of engine **12** is terminated, block **61**. A message may be provided to a user to indicate that a fatal alarm condition is present and that engine **12** has been shutdown.

If a fatal alarm condition is not detected, bi-fuel controller **23** monitors the temperature of temperature sensor **40** within the engine manifold **24**, block **60**. If the temperature within engine manifold **24** is less than a prescribed temperature (e.g., 110 degrees Fahrenheit), bi-fuel controller **23** moves bypass valve **32** to the bypass position such that the output of turbo charger **22** travels along second path **30** and bypasses charge cooler **28**, block **64**. If the temperature within the manifold is greater than 110 degrees Fahrenheit, bi-fuel controller **23** determines if the temperature within engine manifold **24** is greater than a prescribed temperature (e.g., 125 degrees Fahrenheit), block **66**. If the temperature within engine manifold **24** is greater than 125 degrees Fahrenheit, bypass valve **32** is moved to the non-bypass position such that the output of turbo charger **22** travels along first path **26** through cooling charger **28**, block **68**.

In addition to monitoring the temperature of temperature sensor **40** within the engine manifold **24**, bi-fuel controller **23** monitors the power outputted by generator **14** (through monitoring circuit **44**) and the temperature of the coolant flowing through engine **12**, block **72**. If the power generated by generator **14** is less than a predetermined value (e.g., 50 kilowatts) and the coolant temperature of engine **12** is less than a predetermined value (e.g. 160 degrees Fahrenheit), bi-fuel controller **23** maintains gas cut-off valve **25** in the closed position such that no gas is supplied to engine **12**, block **74**. Alternatively, if the power supplied by generator exceeds a predetermined value (e.g., 50 kilowatts) and if the coolant temperature of engine **12** exceeds a predetermined value (e.g. 160 degrees Fahrenheit), bypass valve **32** is moved to the non-bypass position and the gas cutoff valve **25** is open such that gas flows to turbo charger **22**, as heretofore described, block **78**. Thereafter, bi-fuel controller **23** runs knock strategy, block **76**.

Referring to FIG. **3**, once the knock strategy is started, bi-fuel controller **23** monitors the number of knocks detected by knock sensors **34***a*–**34***d* over a predetermined period of time. By way of example, bi-fuel controller **23** may check the status of knock sensor **34***a*–**34***d* every 1.5 seconds, block **80**. The number of knocks detected is compared to the first predetermined level, block **82**. If the number of knocks exceeds a first predetermined level, gas cutoff valve **25** is closed so as to turn-off the gas supplied to turbo charger **22** such that engine **12** runs entirely on diesel fuel, block **84**. In addition, bi-fuel controller **23** advises the user that an alarm condition is present in engine **12**. Thereafter, bi-fuel controller **23** returns to the step of detecting knocks, block **80**

If the number of knocks detected by knock sensors **34***a*–**34***d* does not exceed the first predetermined level, the number of knocks detected is compared to a second predetermined level, block **86**. If the number of knocks detected exceeds the second predetermined level, throttle-body actuator **29** adjusts the flow of gas supplied to turbo charger **22** of engine **12** by a predetermined amount (e.g. 5%) and a gas reduced flag is set, block **88**. Thereafter, bi-fuel controller **23** returns to the step of detecting knocks, block **80**

If the number of knocks detected by knock sensors **34***a*–**34***d* does not exceed either the first or second predetermined levels, bi-fuel controller **23** determines if a gas reduced flag is set, block **90**. If bi-fuel controller **23** determines that the gas reduced flag has been set, bi-fuel controller **23** causes throttle-body actuator **29** to open thereby increasing the flow of gas to engine **12** by a predetermined volume (e.g., 1.5%). The volume of gas provided to engine **12** is limited to a predetermined maximum level, block **92**, that is calculated by bi-fuel controller **23** in response to the magnitude of the output power generated by generator **14** and the temperature at engine manifold **24**. If, after increasing the volume of gas provided to turbo charger **22**, the volume of gas provided is less than the predetermined maximum level, block **94**, bi-fuel controller **23** returns to the step of detecting knocks, block **80**. If, after increasing the volume of gas provided to turbo charger **22**, the volume of gas provided is equal to the predetermined maximum level, bi-fuel controller **23** clears the gas reduced flag, block **96**, and returns to the step of detecting knocks, block **80**.

Returning to FIG. **2**, during execution of the knock strategy, block **76**, bi-fuel controller **23** continues to monitor the coolant temperature of engine **12**, block **98**, the air/fuel mixture temperature in engine manifold **24**, block **100**, and various other conditions on engine **12** such as oil pressure and the like, block **102**. If the coolant temperature exceeds a predetermined threshold, bypass valve **32** is moved by bi-fuel controller **23** to the non-bypass position and gas cutoff valve **25** is closed, block **104**. Similarly, if the temperature of the fuel mixture at engine manifold **24** exceeds a predetermined threshold, bypass valve **32** is moved by bi-fuel controller **23** to the non-bypass position and gas cutoff valve **25** is closed, block **104**. In addition, if any of the other monitored conditions on engine **12** exceed a predetermined threshold, gas cutoff valve **25** is closed, block **106**.

If the coolant temperature exceeds a second predetermined threshold, block **110**, operation of engine **12** is terminated, block **112**. A message may be provided to a user to indicate that a fatal condition is present on generator set **10** and engine **12** has been shutdown. Similarly, if the temperature of the air/fuel mixture in engine manifold **24** exceeds a second predetermined threshold, block **108**, operation of engine **12** is terminated, block **112**. A message may be provided to a user to indicate that a fatal condition is present on generator set **10** and that engine **12** has been shutdown. Further, if bypass valve **32** is locked in the bypass position, block **114**, operation of engine **12** is terminated, block **112**. A message may be provided to a user to indicate that a fatal condition is present on generator set **10** and that engine **12** has been shutdown.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

We claim:

1. A method of controlling a bi-fuel generator set having a controller, a generator for generating electrical power, and an engine for driving the generator, the method comprising the steps of:

providing a flow of gaseous fuel to the engine;

monitoring vibration of the engine during operation and providing a vibration signal to the controller in response thereto;

comparing the vibration signal to a first threshold such that if the vibration signal exceeds the first threshold, the controller reduces the flow of gaseous fuel provided to the engine;

monitoring the electrical power produced by the generator; and

cooling the flow of gaseous fuel provided to the engine if the electrical power exceeds a threshold.

2. The method of claim **1** further comprising the steps of:

providing an air intake for the engine and monitoring the air temperature at the air intake of the engine; and

comparing the air temperature to a threshold such that if the air temperature exceeds the threshold, the controller reducing the flow of gaseous fuel provided to the engine.

3. The method of claim **1** comprising the additional steps:

providing coolant for cooling the engine;

monitoring the temperature of the coolant; and

cooling the flow of gaseous fuel provided to the engine if the temperature of the coolant exceeds a threshold.

4. The method of claim **1** comprising the additional steps of:

providing diesel fuel to the engine; and

adjusting the volume of the diesel fuel provided to the engine in response to the flow of gaseous fuel provided to the engine.

5. The method of claim **1** further comprising the steps of:

providing an air intake for the engine and monitoring the air temperature at the air intake of the engine;

determining a maximum flow of gaseous fuel to the engine in response to a load on the engine and the air temperature at the air intake of the engine; and

comparing the flow of gaseous fuel provided to the engine and the maximum flow of gaseous fuel.

6. The method of claim **5** comprising the additional step of increasing the flow of gaseous fuel provided to the engine if the flow of gaseous fuel provided to the engine is less than the maximum flow of gaseous fuel.

7. The method of claim **1** wherein if the vibration signal is less than the first threshold, comprising the additional steps of:

increasing the flow of gaseous fuel to the engine; and

returning to the step of monitoring the vibration of the engine during operation.

8. The method of claim **1** comprising the additional steps:

providing coolant for cooling the engine; and

monitoring the temperature of the coolant such that if the temperature of the coolant exceeds a first threshold performing the additional step of stopping the flow of gaseous fuel to the engine.

9. The method of claim **8** wherein if the temperature of the coolant exceeds a second threshold performing the additional step of stopping the engine.

10. The method of claim **1** comprising the additional steps of:

monitoring the speed of the engine; and

reducing the flow of gaseous fuel in response to oscillations in the speed of engine.

11. A method of controlling a bi-fuel generator set having a controller, a generator for generating electrical power, and an engine for driving the generator, the method comprising the steps of:

providing a flow of gaseous fuel and a flow of diesel fuel;

combining the flow of gaseous fuel and the flow of diesel fuel to form a fuel mixture, the fuel mixture having a ratio of gaseous fuel to diesel fuel;

providing the fuel mixture to the engine;

positioning a charge cooler remote from a radiator for the engine;

selectively passing the flow of gaseous fuel through the charge cooler in response to a predetermined operating parameter in order to cool the gaseous fuel in the fuel mixture; and

increasing the ratio of cooled gaseous fuel to diesel fuel in the fuel mixture.

12. The method of claim **11** wherein:

the generator set includes coolant provided for cooling the engine;

the predetermined parameter is the temperature of the engine coolant; and

the step of passing the flow of gaseous fuel through the charge cooler includes the additional steps of:

monitoring the temperature of the coolant; and

cooling the flow of gaseous fuel if the temperature of the coolant exceeds a threshold.

13. The method of claim **11** comprising the additional steps of:

monitoring vibration of the engine during operation and providing a vibration signal to the controller in response thereto; and

comparing the vibration signal to a threshold such that if the vibration signal exceeds the threshold, the controller reduces the flow of gaseous fuel.

14. The method of claim **13** wherein if the vibration signal is less than the threshold, comprising the additional steps of:

increasing the flow of gaseous fuel; and

returning to the step of monitoring the vibration of the engine during operation.

15. The method of claim **13** comprising the additional step of comparing the vibration signal to a second threshold such that if the vibration signal exceeds the second threshold, the controller terminates the flow of gaseous fuel.

16. The method of claim **13** wherein the step of adjusting the flow of fuel includes the additional step of comprising the additional step of comparing the vibration signal to a second threshold such that if the vibration signal exceeds the second threshold, the flow of gaseous fuel is terminated.

17. The method of claim **11** comprising the additional steps of:

providing an air intake for the engine and monitoring the air temperature at the air intake of the engine; and

adjusting the flow of gaseous fuel in response to the air temperature at the air intake.

18. The method of claim **11** comprising the additional steps:

providing coolant for cooling the engine;

monitoring the temperature of the coolant such that if the temperature of the coolant exceeds a first threshold performing the additional step of stopping the flow of gaseous fuel.

19. The method of claim **18** wherein if the temperature of the coolant exceeds a second threshold performing the additional step of stopping the engine.

20. The method of claim **11** comprising the additional steps of:

monitoring the speed of the engine; and

reducing the flow of gaseous fuel in response to oscillations in the speed of engine.

21. A method of controlling a bi-fuel generator set having a controller, a generator for generating electrical power, and an engine for driving the generator, the method comprising the steps of:

providing diesel fuel to the cylinders of the engine for ignition;

providing a flow of gaseous fuel to the engine;

monitoring the operating conditions of the engine and the generator;

adjusting the flow of gaseous fuel to the engine in response to predetermined operation conditions on the engine;

monitoring the electrical power produced by the generator; and

cooling the gaseous fuel provided to the engine if the electrical power exceeds a threshold.

22. The method of claim **21** comprising the additional step of cooling the flow of gaseous fuel provided to the engine.

23. The method of claim **22** wherein the step of cooling the flow of gaseous fuel includes the steps of:

providing coolant for cooling the engine;

monitoring the temperature of the coolant; and

cooling the gaseous fuel provided to the engine if the temperature of the coolant exceeds a threshold.

24. The method of claim **21** wherein the step of monitoring the operation conditions of the engine includes the step of monitoring vibration of the engine during operation and providing a vibration signal to the controller in response thereto, and wherein the step of adjusting the flow of gaseous fuel includes the step of comparing the vibration signal to a first threshold such that if the vibration signal exceeds the first threshold, the flow of gaseous fuel provided to the engine is reduced.

25. The method of claim **24** wherein if the vibration signal is less than the first threshold, the step of adjusting the flow of fuel includes the additional steps of:

increasing the flow of gaseous fuel to the engine; and

returning to the step of monitoring the vibration of the engine during operation.

26. The method of claim **21** wherein the step of monitoring the operating conditions includes the step of monitoring the air temperature at the air intake of the engine.

27. The method of claim **21** wherein the step of monitoring the operating conditions includes the step of monitoring the temperature of the coolant such that if the temperature of the coolant exceeds a first threshold performing the additional step of stopping the flow of gaseous fuel to the engine.

28. The method of claim **27** wherein if the temperature of the coolant exceeds a second threshold performing the additional step of stopping the engine.

29. The method of claim **21** wherein the step of monitoring the operating conditions includes the step of monitoring the speed of the engine and wherein the step of adjusting the flow of fuel includes the step of reducing the flow of gaseous fuel provided to the engine in response to oscillations in the speed of the engine.

30. A method of controlling a hi-fuel generator set having a controller, a generator for generating electrical power, and an engine for driving the generator, the method comprising the steps of:

providing a flow of gaseous fuel;

positioning a charge cooler remote from a radiator for the engine;

passing the flow of gaseous fuel through the charge cooler to selectively cool the flow of gaseous fuel; and

providing the cooled flow of gaseous fuel to the engine;

wherein the step of passing the flow of gaseous fuel through the charge cooler includes the additional steps of:

monitoring the electrical power generated by the generator; and

cooling the flow of gaseous fuel if the electrical power exceeds a threshold.

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